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**Method For Attenuating A Heat Flow**
**And Apparatus For Protecting A Monitor Operator**

This invention relates to the fire-prevention equipment and may be applied for protecting the equipment and people during fighting a fire, for dividing the area of buildings, ground and underground structures and apparatus into fire-checking sections, preventing fall of ceilings and intermediate floors, and stopping the spread of large fires entailing environmental catastrophe.

The method closest in terms of technical essence to the one proposed by present invention consist in creating a vertical fire protection curtain, which is formed by installation of metal nets arranged as two parallel surfaces and supply of cooling agent in the space between them. Water, water with surface-active substance or air-mechanical or chemical foam may be used as a cooling agent [1].

The disadvantage of the known method is that the only one protecting curtain and only one cooling agent used. This does not guarantee absolute safety when applied.

There exists apparatus attached to the monitor to protect from heat radiation [2]. It contains a sprinkling assembly, which consists of a V-shaped water stream splitter, two parallel plates, a mechanism for changing the angle between the plates of the V-shaped splitter. Water supplied under pressure through the monitor casing enters the sprinkling assembly. There it changes its direction and spreads over the plates forming two thin water films separated by the layer of air.

The disadvantage of this apparatus is that it requires a fixed pressure of water in order to maintain the aforementioned water films in a stable state.

However this condition is difficult to ensure since water pressure is not stable and difficult to control. Furthermore, the monitor cannot change its position, which is a disadvantage too.

The apparatus closest in terms of technical essence to the one proposed by present invention is described in [3]. It is attached to the monitor and contains a sprinkling assembly joined with the monitor casing. This sprinkling assembly is placed on the support and made in the form of a frame of communicating tubes placed both horizontally and vertically. There are openings for sprinkling water on the surface of the tubes, and in central part of the frame there is an aperture for vertical movement of the monitor nozzle. The frame equipped by two metal nets fixed on both side of the frame at some intervals; the lower part of the frame is equipped by rollers, which enable the frame to move along the support equipped by an arched guide for the rollers.

The disadvantage of this apparatus is that at any water pressure in the monitor water from openings on surface of tubes discharges in the form of thin streams. These streams disintegrate into drops only at the points where the streams bump against the frame and the metal nets. As a result the continuous water screen is not formed.

Another disadvantage of this apparatus is that it requires the use of both hands to turn the protecting screen horizontally. When such movement is performed, the reactive force created by the outgoing water sends the monitor into vertical random movement inside an aperture of the frame. This, in its turn, may bring undesirable consequences.

The objective of the present invention is to provide a higher efficiency heat flow attenuation method and an apparatus easier to use, which have a higher degree of safety and provides protection of a monitor operator against convection gas flows and the flows of heat and visible spectrum radiation .

The objective of the present invention is achieved by applying the heat flow attenuation method consisting in the creation of the fire protection curtain

by supplying a cooling agent in the space formed by at least two surfaces, with the difference that this curtain is created by means of controlled enlargement of the surface of interaction of a cooling agent with the flows of heat and visible spectrum radiation (e.g. by means of controlled sprinkling or controlled spraying the liquid or ejecting a compressed gas or bubbling).

When more than one curtain is formed, a combined supply of cooling liquid is used.

At least one of the curtains is formed by spraying the liquid, whereas the rest ones by supplying air-mechanical or chemical foam.

The objective of the present invention is also achieved by using sprayers designed for spraying the cooling liquid into fine-disperse states and attached the openings of the tubes of the frame of the apparatus, which is designed to protect of a monitor operator and contains sprinkling assembly (placed on the support connected with the monitor casing and made in the form of a frame of communicating tubes arranged both horizontally and vertically and having openings on their surfaces), an aperture for monitor casing in central part of the frame, and protective surfaces (e.g. nets) fixed at some interval along both sides of the frame.

The nets are wattled and/or perforated and/or punched.

The nets are made of powder metallurgy products.

The nets are made of fireproof plastic.

The nets are made of copper.

The nets are made of a material coated by a metal film.

The nets are made of a galvanized steel.

The size of a net cell is $0.1 \times 0.1 - 8.0 \times 8.0$ mm.

An interval between the frame and protective surface is 1-200 mm.

The characteristics of the external net (the diameter of a wire, the material, the size of a cell, the type: wattled, perforated, punched) are identical with those of the internal net.

The characteristics of the external net (the diameter of a wire, the material, the size of a cell, the type: wattled, perforated, punched) are different from those of the internal net.

The frame is arranged at the forward part of the monitor and at its sides.

The frame is arranged along the perimeter around the monitor, and, if need be, at the ceiling and the bottom of it.

The essence of the present invention lies in fact that the cooling liquid is supplied between the protective surfaces in the form of a flow of the separate drops formed by means of special sprayers. This sprayed flow is characterised by the dispersity of liquid, the size of drops, distribution of the drops over the cross-section, the taper angle, the action range, the liquid pressure at the sprayer, and the quantity of consumed liquid. In practice centrifugal, pneumatic and mechanical ways of spraying are widely used [4].

The average diameter of drops decreases with an increase of the liquid pressure at the sprayer.

The fire pumps supply water under a pressure of 1.2 MPa; in so doing the average diameter of sprayed liquid drops is equal 400-500 micron. When devices of high pressure are used the differential in pressure inside sprayers may reach 15 MPa; in this case the diameter of drops may be reduces to 5-10 micron. Absorbing the heat radiation, the drops of sprayed liquid are starting to evaporate when they approach the protective surfaces as well as come in contact with these surfaces; it is enhanced by the fact that the drops of liquid with high kinetic energy are reflected repetitively from protective surfaces in space between them. The type and material of the protective surfaces, e.g. in the form of nets, their characteristics, the size of the nets cell, diameter and the material of the wire, etc. are chosen so that a cooling liquid film is being formed as a result of surface tension. The consistency of the film is maintained by dynamic equilibrium between the process of its evaporation, while heat energy is

absorbed , and the process of constant supply the liquid into the film, when the sprayed liquid drops bump against the film.

Thus, there is a medium formed of vapour, cooling liquid drops and air (a vapour-drop-air medium) in the space between the surfaces. The flows of heat and visible spectrum radiation, as well as convection gas flows is partly reflected from these surfaces (e.g. from the nets), from the cooling liquid films and the vapour-drop-air medium. In addition the heat energy is partly absorbed by these films and medium and "channelled" perpendicularly to the direction of the attacked heat flow movement.

It is obvious that the symbiosis of the above-mentioned processes of reflection and absorption determines one unique feature of the apparatus under consideration: the efficiency of the screening effect against the attacking heat flow increases along with growth of the intensity of this heat flow.

The spraying of the cooling liquid into fine dispersion state by means of the high pressure devices, so that diameters of drops are comparable with the wavelengths of heat radiation (1.5-7 micron), also adds to the increase in the heat flow screening efficiency by the apparatus under consideration. In accordance with the laws of geometrical optics, the scattering of the heat radiation increase several times if dispersity of the liquid drops are optimal [5].

The necessity of controlling the quantity $M$ of cooling liquid supplied into the space between protective surfaces (they may be made of metal fabric, glass fabric, metal plates or other materials) is caused by considerable variation of the value of heat flows $W$ which take place at fires (from 0 to 200-250 kw/m$^2$). A special protection is required for fire-fighters if $W \cong 3\text{-}4$ kw/m$^2$.

Let us assume that the heat flow $W_0$ falls perpendicularly on the surface of the fire protection screen:

$$W_0=W_1+W_2+W_3$$

where $W_1$ is the part of heat flow reflected from the screen, $W_2$ is the part of heat flow penetrated through the screen, $W_3$ is the part of heat flow absorbed

by the cooling liquid of the screen. Obviously, with the changing of M, $W_3$ is changed mostly.

Let us consider a hypothetical case where the heat flow $W_0$ is totally absorbed by the cooling agent (by the water in particular).

Let us assume that 100 gm. of water is sprayed into the 1 $m^2$ space between the screen nets. Let us estimate the $W_0$ assuming that the heating up to 100°C as well as vaporisation run during 1 second.

In this case

$$Q_0 = Q_h + Q_s$$

where

$Q_0$ is the total quantity of heat,

$Q_h = CM(t_2 - t_1)$ is the quantity of heat required for the heating from temperature $t_1$=0°C to temperature $t_2$ = 100°C of 100 gm. of water with specific heat $C$=4.2 kj $kg.^{-1}$ $deg^{-1}$,

$Q_s = \lambda M$ is the vaporisation heat,

$\lambda = 22.6 \cdot 10^2$ kj/kg. is the specific evaporation heat of water.

$$Q_0 = 4.2 \cdot 10^4 \text{ j} + 22.6 \cdot 10^4 \text{ j}.$$

Notice that $Q_s$ is more than $Q_h$ by the factor of 5.

For the case under consideration such value of $Q_0$ corresponds to $W_0$ = 268 kw/$m^2$.

Heat flows with such volume of $W_0$ are seen at large fires on timber warehouses. When a gas gusher is in flame, the heat flow may be as much as 30-40 kw/$m^2$. Largest attenuation of $W_0$ by vapour-drop-air medium can be obtained if the average diameter of water drops is comparable to the wavelength of the heat radiation (5-10 micron) [5].

In this case a 5-7 times attenuation was achieved experimentally. Since speed of water drops was 10 - 100 m/sec, the process of steam generation is of little significance for the absorption of heat.

The attenuation of $W_0$ by the factor 4-5 was obtained using a curtain of only one net cooled by water [6].

In the case where a curtain with two nets placed at some interval is employed, the water drops are reflected repeatedly from surfaces of the nets in the space between of them. This phenomenon is accompanied by the following processes: slowing of the speed of drops, splitting of drops into more fine ones, adhering of some drops on the nets. As a result of the aforementioned process there appears a water film on the surface of the net wire, besides, a water film is formed the net cells if the size of the net cells allows it. Owing to these processes, the absorption of the attacking heat flow increases since it goes on heating and evaporation the drops and films of water. Besides, the two protecting surfaces increase the process of dissipation and reflection of heat flows and convective gas flows – $W1$. This dissipation and reflection is effected both by the nets and the water film, formed on the net surface, as well as by a vapour-drop-air medium formed in the space between the nets.

It is important to note that during the experiments it was possible to observe the interaction between the flows of the infrared and visible spectrum radiation visible and convective gas flows with the vapour-drop-air medium formed immediately in front of the protecting screen on the side of the heat flow falling.

When the water drops collide with the protecting nets, drops split into even finer ones; several of those go out of the space between the net surfaces. Fine-dispersed water splashes, passed through the forward net (it is arranged on the side of the falling of the heat flow) and evaporating water steam form a visually observable layer consisting of a vapour-drop-air medium and adjacent to the external surface of the frontal net, facing towards the fire.

The interaction between the convection flows of hot gases, falling on the frontal net surface facing towards the fire and reflected from them with this external layer of vapour-drop-air medium causes the visually observable

unstable pulsation of this medium and "running" down of heat energy along the frontal net surface in direction that is perpendicular to the direction of the vector of the heat flow ($W_0$) expansion.

Thus, the proposed method for attenuating a heat flow differs essentially from the known ones. It qualitatively changes the situation in cases when the process of absorption and evaporation begin to play a considerable role in attenuation of heat flows. As was shown by the above calculations, theoretically these processes are capable to solve the problem of protecting from heat affection even at largest fires. It should be noted that in this method $W_1$ and $W_2$ increase with increasing $W_0$, i.e. during the functioning of the screen there is a self-regulating attenuation of the falling heat flow. At the same time, the present invention makes for the regulation of this process by artificial means, since the degree of attenuation of the falling heat flow essentially depends on the processes of absorption and evaporation. This regulation may be performed either automatically (by means of computer program, receiving data from the heat sensor) or manually. Experimentally, the regulation was performed by closing and opening of some of the sprayers, supplying water into the space between the nets, or by changing the pressure of water or any other cooling agent. The artificial regulation of attenuation of the falling heat flows makes possible obtaining the desired attenuation of $W_0$ with economical consumption of water, that is used for forming and maintaining the vapour-drop-air medium.

The addition of colour agents to the supplied liquid, increases the efficiency of the heat screening by the present device, since in this case the absorptivity of falling energy by the vapour-drop-air medium will increase [7].

When the sprinkling assembly is made as a system of sprayers arranged by special way on the frame, it allows to ensure a homogeneous distribution of drops of the liquid in the space between the surfaces, or the nets, that fixed on both side of the frame at some interval from each other.

If the protecting screen is made in the form of a semicircle, it allows to protect the monitor operator against hazardous factors of fire at the front and the sides. In order to put out a fire on especially dangerous objects, the screen may be arranged along the perimeter of the monitor as well as on top of it. In this case the monitor operator will be screened from the front, the sides, the rear and from above.

If all the construction is placed on the wheeled flat-car, it will make it easily movable. If it is equipped with a drive, it will make the construction mobile.

The invention is illustrated by drawings: Figure 1 shows the general view of the steady-state apparatus for protecting a monitor operator (this is one of the option for the realisation of the above-mentioned heat flow attenuation method); Figure 2 shows a top view of the apparatus; Figure 3 shows a fragment of the sprinkling assembly with sprayers (View A of Figure 1); Figure 4 shows a side view of the apparatus; Figure 5 shows a top view of the apparatus with a screen located round the periphery of the monitor operator; Figure 6 shows the apparatus equipped with wheels and a drive.

The apparatus for protecting a monitor operator by means of the fire protection screen include the monitor 1 on the support 2. The support analogous with that of the monitor or the frame of the sprinkling assembly can be used in capacity of the latter. The sprinkling assembly is made in the form of a frame 3 of communicating tubes 4 placed both horizontally and vertically. The tubes 4 are equipped with sprayers 5. In central part of the frame there is an aperture 6 for vertical movement of the monitor nozzle 1. The frame 3 equipped by two metal nets 7 and 8, which are fixed on both side of the frame at some intervals (in Figures 2 and 4 these nets are shown by special hatching; in Figures 5 and 6 some fragments are shown by the same hatching; in Figure 1 it is shown by perpendicular lines 9, which graphically represent the net cells without regard to the scale). The support 2 has an arched guide 11 of radius R, and the frame 3 has

rollers 10 placed at its bottom. Thanks to these rollers the frame can be moved along the support. The monitor 1 has a handle 12. The frame 3 of the communicating tubes 4 and the nets 7 and 8 form a fire protection screen.

The vertical axis of rotation $O_1$ of the monitor is shifted away from the vertical axis of rotation $O_2$ of the fire protection screen towards the screen 3. Owing to the shift, a monitor operator is closer to the screen 3 and consequently more protected.

The support 2 connected with the monitor 1 is placed on the platform 13, which equipped with wheels 14 and motor 15. The fire protection screen 3 may be arranged so that a monitor operator will be protected from the front and the sides (Figure 2), or it may be arranged along the perimeter protecting a monitor operator from the front, the sides, the rear and from above (Figure 5 and 6). The nets 7 and 8 of the fire protection screens 3 may be wattled or perforated. In the former case, the diameter of the wire may vary in the range from 0.1*0.1 mm - 8.0*8.0 mm. The wire in diameters under 0.1 mm is not capable to resist mechanical tensions, whereas the use of wire in diameters over 3.0 mm leads to the increasing of weight of the screen, with the result that the apparatus loses its manoeuvrability. The size of the wattled net cells may vary in the range from 0.1*0.1 mm - 8.0*8.0 mm depending on the diameters of the wire. The net, that is exterior with regard to the monitor operator, may be made from thicker wire and with larger cell size.

The nets may be made of wire with the same diameters, and their cells may be uniform in size. The nets may be made using any wires, e.g. manufactured of metals (copper, brass or any other), ceramics or products of the powder metallurgy. The net may be made of fire proof plastic. The nets may be perforated or punched.

The fire protection screen, which includes two protective surfaces in the form of nets (the net 7, that is internal surface, and the net 8, that is external surface), can be made as a combination of surfaces in various types. For

example, the external surface may be made as net (wattled, perforated or punched), whereas the internal surface may be made of metal sheet, transparent fireproof polymer, which may be reinforced by metal net, or it may be made as compound one (e. g., it is a net on the level of the operator's eyes internal surface 7 is made in the form of a net, whereas the rest of it is the metal sheet).

The apparatus works as follows : at the fire water or any other liquid (water with surface-active substances, foam-generating solutions, etc.) through the communicating tubes ( not shown on the Fig.) is supplied to the monitor 1 and through the system of tubes 4 is further supplied to the sprayers 5. A powerful jet of water is supplied to the fire-core by means of the monitor, and simultaneously the liquid is sprayed by means of the sprayers 5 in the space between the nets 7 and 8. The liquid, sprayed by the sprayers, and vapour, generating as a result of interaction of the heat flow and sprayed water drops, create in the space between the nets a vapour-drop-air medium, which effectively reflects and absorbs the heat flows and therefore, ensures the safe working condition for the monitor operator. Additionally, a silhouette visibility of the situation at the fire-site is ensured.

Apart from self-controlling increase in attenuating of heat flow, a regulated attenuation by means of existing methods (computer systems of automatic regulation or manual methods of regulations) is ensured.

This kind of regulation can be achieved by placing the heat sensors with spectral diapason including a visible and infrared spectrum of radiation in front of the protecting screen.

During the fire computers systems constantly receives information the sensors, and introduces necessary corrections in the number of sprayers, water pressure and the quantity of foam supplied into the space between the nets.

This regulation of the protecting qualities of the screen may be effected by the monitor operator themselves by the existing methods.

When the protecting screen 3is placed on rollers, it makes it possible to turn it around vertical axis $O_2$ and to fix it in the desired direction by means of a handle 12.

The same handle allows the vertical movement of the monitor in accordance with the desired angle with regards to the horizon to supply the cooling liquid to the desired distance.

A combined curtain is used to safeguard the life of people at the places with the concentration of large number of people, e.g. specific anti-fire curtain at theatres. In this case, the curtain, the first on the side of the stage is formed by the two surfaces and water sprayed between them; the second curtain is formed by supplying foam into the space between the second and third surfaces. In this case, a step-by-step attenuation of the powerful heat and gas flows at strong fire on the stage. The vapour-drop-air curtain, next to fire, is the first to reduce the heat flows and protect the next foam curtain against destructive impact of heat. All aforementioned allows to increase the efficiency and longevity of this combined curtain at extreme situations, e.g. in the moment prior to the evacuation of people from the theatre hall; it also allows to stop the penetration of toxic gases into the theatre hall.

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